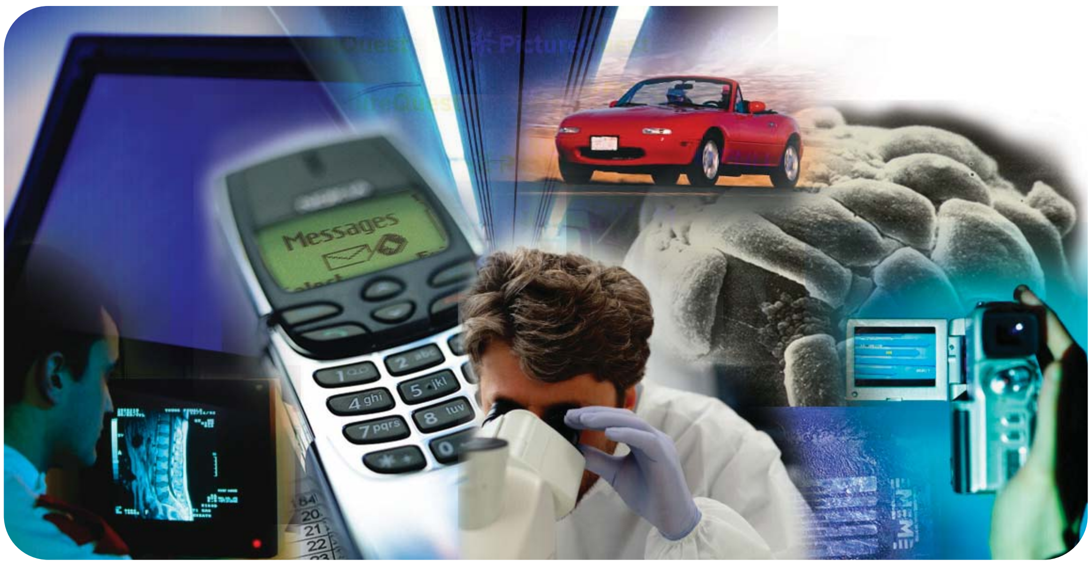
TECHNOLOGY *Opportunity*

ELECTRONICS AND MATERIALS

Producing lower cost Single-Walled Carbon Nanotubes *without metal catalysts*

NASA seeks companies to license this new low-cost, high-yield process.



NASA Goddard Space Flight Center has made a major step forward in reducing the cost of manufacturing single-walled carbon nanotubes (SWCNTs). Most manufacturing methods, which use a metal catalyst to form the tubes, have several drawbacks that have impeded development of SWCNTs' numerous applications. NASA researchers have discovered a simple, safe, and inexpensive method to create SWCNTs without the use of a metal catalyst.

Benefits

- ***Less expensive:*** NASA's SWCNT manufacturing process eliminates the costs associated with the use of metal catalysts, including the cost of product purification. As a result, the manufacturing cost can be reduced significantly for high-quality, very pure SWCNTs.
- ***More robust product:*** Because NASA's process does not use a metal catalyst, no metal particles need to be removed from the final product. Eliminating the presence of metallic impurities results in the SWCNTs exhibiting higher degradation temperatures (650 °C rather than 500 °C) and eliminates damage to the SWCNTs by the purification process.
- ***Simpler and safer:*** Unlike most current methods—which require expensive equipment (e.g., vacuum chamber), dangerous gases, and extensive technical knowledge to operate—NASA's simple SWCNT manufacturing process needs only an arc welder, a helium purge, an ice-water bath, and basic processing experience to begin production.
- ***Higher yield:*** Traditional catalytic arc discharge methods produce an "as prepared" sample with a 30% to 50% SWCNT yield. NASA's method produces SWCNTs at an average yield of 70%.

National Aeronautics and Space Administration

Commercial Applications

Carbon nanotubes are being used in a wide variety of applications, and NASA's improved production method should increase their prevalence in the following areas:

- ***Medical:*** SWCNTs offer the opportunity for improved medical treatments:
  - Implantable defibrillators (pacemakers)
  - Portable/Field equipment
  - Implantable biosensors
  - Improved hearing aids
  - Electrochemical analysis of biological materials
  - Delivery of medicines and other treatments at the cellular level
- ***Microelectronics:*** SWCNTs offer low resistivity, low mass density, and high stability for improved:
  - Microcircuits, nanowires, and transistors for miniature electronics
  - Consumer products, including pagers, cell phones, laptop and handheld computers, toys, power tools, and automotive components
- ***Scanning Force/Tunneling Microscopy:*** Probing tips made with SWCNTs last longer and perform better than conventional silicon tips, improving:
  - Materials science research and development
  - Production quality control of semiconductor materials and data storage media
  - Evaluation of biological samples
- ***Materials:*** SWCNTs do not affect a polymer's mechanical properties, allowing stress, transition, and thermal strain to be observed. SWCNTs also can be used to reinforce composites. Applications include:
  - Dopants to create electrically conductive polymers
  - Composites for long-lasting bone and joint implants
  - Easier monitoring of composites in critical applications (e.g., aircraft)
- ***Molecular containment:*** SWCNTs can be used to contain various elements:
  - Hydrogen for fuel cells
  - Lithium boron hydrate for radiation shielding

The Technology

Although carbon nanotubes have drawn significant attention from the scientific community since their discovery in 1991, SWCNT production methods are complex, dangerous, and expensive. Most methods—chemical vapor deposition, laser ablation, microwave, and high-pressure CO conversion (HiPco)—use a metal catalyst to encourage carbon to grow in nanotube form without capping. However, the use of a metal catalyst dramatically increases the pre- and postproduction costs.

NASA scientists have developed an SWCNT manufacturing process that does not use a metal catalyst, resulting in simpler, safer, and much less expensive production. Researchers used a helium arc welding process to vaporize an amorphous carbon rod and then form nanotubes by depositing the vapor onto a water-cooled carbon cathode. Analysis showed that this process yields bundles, or "ropes," of single-walled nanotubes at a rate of 2 grams per hour using a single setup.

NASA's process offers several advantages over metal catalyst production methods. For example, traditional catalytic arc discharge methods produce an "as prepared" sample with a 30% to 50% SWCNT yield at a cost of approximately $100 per gram. NASA's method increased the SWCNT yield to an average of 70% while significantly reducing the per-gram production cost. Additional research is needed to determine the physical characteristics of NASA's SWCNTs.

Licensing/Partnering Opportunities

This technology is part of NASA's technology transfer program. Companies are invited to license this technology and/or partner with Goddard Space Flight Center for additional research.

For More Information

If you are interested in licensing this technology or in joint research, please contact:

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